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ABSTRACT

This manual, one in a series developed for public education, provides information on smoke detector selection, installation, operation, and maintenance. For the prospective buyer, the importance of looking for the seal of a recognized national testing laboratory--such as Underwriters' Laboratories, Inc. (UL)--indicating adequate laboratory testing is discussed followed by a description of the two basic types of detectors (ionization and photoelectric) and how they work. Proper placement and installation procedures are also covered, including the number needed, location, power sources, and interconnection of alarms. Concluding the manual is a discussion of basic alarm maintenance and testing procedures, and the factors to consider in developing an escape plan in the event of a fire. (Related documents include Smoke Detectors and Legislation, CE 017 147, and Smoke Detector Resource Catalog, CE 017 146.) (JH)

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SMOKE DETECTOR TECHNOLOGY

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U.S. DEPARTMENT OF COMMERCE
National Fire Prevention and Control Administration
Public Education Office

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CE017 148

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July 1977

TO THE READER:

To help you meet the challenge and opportunity of a smoke detector campaign in your community, the National Fire Prevention and Control Administration has prepared a series of smoke detector public education manuals. Written in cooperation with the National Bureau of Standards, these manuals are largely based on successful local programs. The five manuals illustrate a coordinated effort within the NFPCA. Research, data, fire service training, and public education each are important elements of our smoke detector activities.

Within the Federal government, the National Bureau of Standards, the Consumer Product Safety Commission, and the Department of Housing and Urban Development are all making unique contributions to smoke detector public acceptance. In the private sector, the National Fire Protection Association is actively involved in smoke detector installation standards development.

These manuals are presented in the full knowledge that while smoke detectors are essential, they are only part of your overall fire safety efforts. We hope you find them useful in your smoke detector public education campaign.

Howard D. Tipton

Howard D. Tipton
Administrator
National Fire Prevention and Control Administration

VOLUME I: The Smoke Detector Resource Catalog
A fact sheet on smoke detectors, guides to finding smoke detector materials, case histories of successful programs, a legislative overview, and evaluation techniques.

VOLUME II: Moving the Public on Smoke Detectors
A two-part manual on generating support through community organizations and the media.

***VOLUME III: Smoke Detector Technology**
A detailed description of smoke detector operation, selection, installation and maintenance.

VOLUME IV: Smoke Detectors and Legislation
An in-depth review of the current status of state and local smoke detector legislation.

VOLUME V: Smoke Detector Training
A suggested curriculum for training members of the fire prevention community to present smoke detector education to the public.

*contained in this Manual

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SMOKE DETECTOR TECHNOLOGY

ABSTRACT

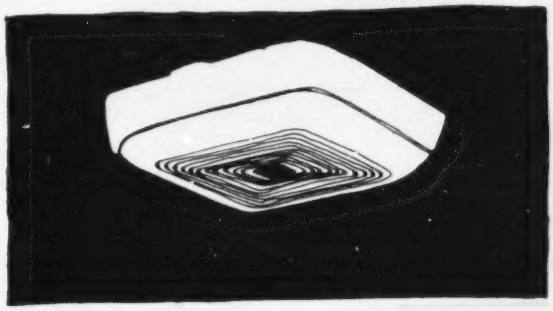
WHY SMOKE DETECTORS?

Smoke detectors save lives. Increasingly, communities across the country report families saved from certain tragedy by the early warning provided by residential smoke detectors. This early evidence of effectiveness points out an opportunity for dramatically reducing the 6,600 residential fire deaths that occur every year in the United States.

LABORATORY LISTED

While a comparatively new technology, smoke detectors work. They have proven effective both in the testing laboratory and in those real-life situations where they had to perform. The laboratory test is important for prospective purchasers. Smoke detector buyers should consider only those models listed or approved by a nationally recognized testing organization such as Underwriters' Laboratories, Inc.

TWO BASIC TYPES AVAILABLE



There are two basic types of residential smoke detectors: ionization and photoelectric. The ionization detector uses a very small amount of radioactive material to produce electrically charged materials called ions. The photoelectric detectors use either an incandescent light bulb or a light-emitting diode (LED) to send forth a beam of light.

PLACEMENT AND INSTALLATION

Proper placement and installation of your smoke detectors are important for performance and safety. Users should follow the manufacturers' instructions. Additional details are provided on page 8 of this Manual.

MAINTENANCE AND TESTING

Maintaining and testing residential smoke detectors are simple, routine, and extremely important procedures. Smoke detectors may be called upon only once, but that one time is crucial.

ESCAPE PLANNING

While smoke detectors are important, they are only the first step in what should be a well thought-out and practiced home escape plan.

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LABORATORY LISTED

Almost 90 different companies now manufacture or distribute hundreds of models of residential smoke detectors. The growing array of smoke detectors and various advertising claims have caused some confusion among a public presented with a new technology.

USING THIS CHAPTER

Listing or approval by a nationally recognized testing laboratory is the primary selection factor in smoke detectors. The fire prevention educator needs to understand how listing or approval is acquired to assist the public in making informed purchase decisions.

LOOK FOR THE SEAL

Prospective purchasers should only consider smoke detectors with the seal of a nationally recognized testing laboratory. This seal shows that the manufacturer has met some minimum standards and has exercised some quality control in the production process. Underwriters' Laboratories, Inc. (UL) provides such testing services and lists those detectors which have passed its standards. They also offer follow-up services, such as routine inspections of manufacturing facilities and periodic product testing.

ADDITIONAL APPROVALS

Model building code authorities and state or local fire marshals may provide supplementary approval of smoke detectors. Normally, this approval is not based on additional testing, but relies on UL test results.

Approvals by model building code authorities verify that detectors meet those performance specifications included in their model building codes. This process usually includes a review of the testing laboratory report, and of the sales and technical literature provided with the product.

Fire marshals sometimes require approvals to provide some control over the products sold in their jurisdictions. If a particular model encounters field problems, a fire marshal has the authority to remove that model from the approved list, effectively denying future sales in his area until the problem is corrected.

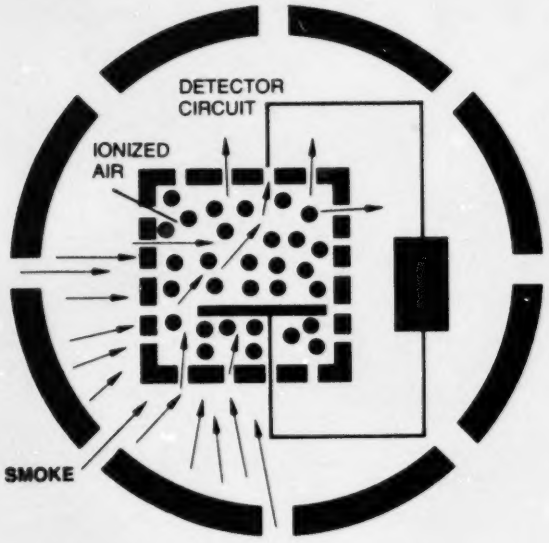
TWO TYPES

TWO TYPES TO CHOOSE FROM: IONIZATION AND PHOTOELECTRIC

Available smoke detectors operate on one of two basic principles: ionization and optical (photoelectric). For maximum protection, the user should understand the advantages and disadvantages of both types.

HOW THE IONIZATION SMOKE DETECTOR WORKS

The ionization detector uses a small amount of radioactive material to make the air within a sensing chamber conduct electricity. When very small smoke particles enter the sensing chamber, they interfere with the conduction of electricity, reducing the current and triggering the alarm. The particles to which the detector responds are often smaller than can be seen with the human eye. Since the greatest number of these invisible particles are produced by flaming fires, ionization detectors respond slightly faster to open flaming fires than photoelectric detectors.



The radiation source in ionization detectors is *not a hazard*. Before the detectors are placed on the market, the U.S. Nuclear Regulatory Commission (NRC) performs a radiation safety analysis to determine that detectors meet safety requirements. In addition, Consumers Union has conducted independent studies and confirmed that there is no radiation danger from ionization detectors.

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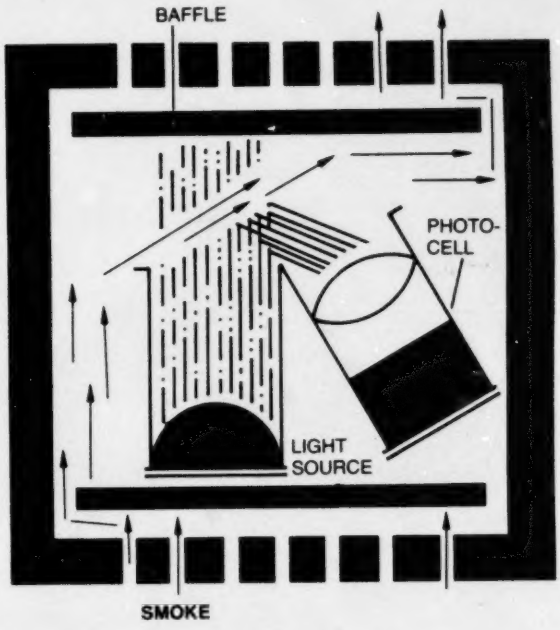
THE PHOTOELECTRIC DETECTOR AND HOW IT WORKS

The photoelectric detector uses a small light source—either an incandescent bulb or a light emitting diode (LED)—which shines its light into a dark sensing chamber. The sensing chamber also contains an electrical, light-sensitive component known as a photocell. The light source and photocell are arranged so that light from the source does not normally strike the photocell. When smoke particles enter the sensing chamber of the photoelectric detector, the light is reflected off the surface of the smoke particle, allowing it to strike the photocell and increase the voltage from the photocell. (This reflection of light is the same means by which we see smoke in the air. That is, light from the room strikes the smoke and reflects it to our eyes.) When the voltage reaches a pre-determined level, the detector alarms.



Smoke particles that scatter visible light are larger in diameter than those which an ionization detector senses. Since smoldering fires produce these larger smoke particles in their greatest numbers, photoelectric detectors respond slightly faster to smoldering fires than ionization detectors.

In general, the size of the average smoke particle from a fire is inversely proportional to the combustion temperature. That is, the higher the temperature, the smaller the average particle size.

COLOR A FACTOR

The color of the smoke particles also affects the response of the photoelectric cell. Black smoke particles, such as those from burning plastics or flammable liquids, absorb a portion of the light striking them, causing less light to reflect into the photocell. Thus, it can take five times as much black smoke to alarm a photoelectric detector as a grey or white smoke. However, since most residential fires involve a mix of fuels producing generally lighter smokes (rather than only flammable liquids or plastics), color is not as critical a factor in residential smoke detection as might be thought.

IONIZATION VS. PHOTOELECTRIC: BOTH TYPES ARE EFFECTIVE

Even though the average particle size changes considerably with temperature, all fires produce a broad range of particle sizes. Therefore, both types of detectors will detect most fires. And while there will be some variation in the detector response time, the differences are fairly small when compared to the amount of escape time the detector provides. Numerous field tests have shown that either type of detector, when correctly installed, will provide adequate warning for escape.

HEAT DETECTORS PROVIDE ADDITIONAL PROTECTION

Smoke detector users can obtain additional protection by installing heat detectors in unoccupied areas where smoke would be contained and delayed in reaching remote smoke detectors. These areas include attics, garages, furnace or utility rooms, or any other small room normally closed off from the main portion of the house (by a closed door, for example). In fact, some smoke detector manufacturers do not recommend placing their units in attics, garages, or furnace and utility rooms due to smoke detector sensitivity to temperature extremes and/or fumes.

Smoke from fires originating in these areas generally will not be detected by smoke detectors until they break into the living area (already protected by smoke detectors).

Therefore, these additonal heat detectors may impact on life safety. Early warning of fires in both occupied and unoccupied areas could reduce property loss. Prospective heat detector purchasers should look for units with the largest UL spacing rating—the larger the rating, the more rapid the heat detector response.

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PLACEMENT AND INSTALLATION

USING THIS CHAPTER

The location of smoke detectors and the installation of the units are both critical to detector sensitivity and performance. Combined with the manufacturer's instructions, the information in this chapter will allow fire educators to respond to consumer questions about placing and installing residential smoke detectors.

HOW MANY AND WHERE?

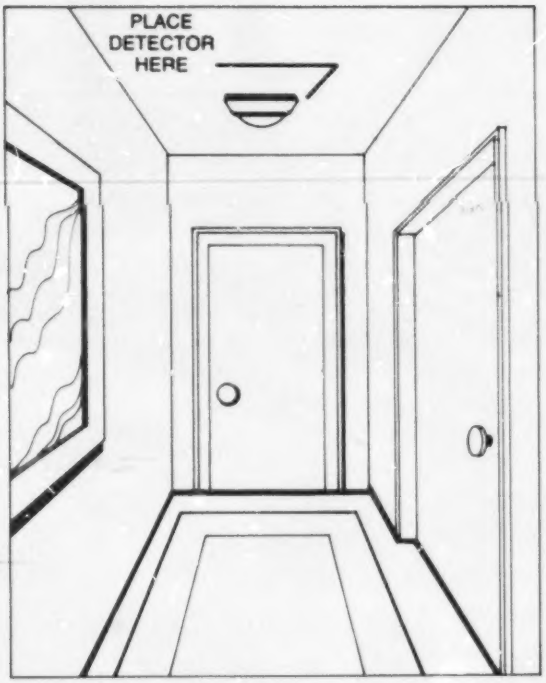
Extensive field tests show that installing a smoke detector on *every level* of a house provides the best all-around protection for the least investment. Though a smoke detector in every room will provide the fastest detection times, the modest increase in escape time may not justify the additional expense.

At the minimum, users should install a smoke detector in the hallway outside each sleeping area. The detectors should be close enough to the bedrooms so that the alarm can be heard with the bedroom door closed. People who normally sleep with the bedroom door closed may wish to consider adding an additional detector inside the bedroom.

Since many home fires start in basements, homes with basements should have a detector on the basement ceiling at the entrance to the steps.

MORE REASONS FOR DETECTORS ON EVERY LEVEL

Field tests also show that some conditions in multi-story living units can delay the smoke detector alarm until after the primary exit is blocked. This situation can occur when the air conditioning system is operating, and the detector and the fire are on different floors. The air conditioning creates a flow of cold air down stairways. This flow prevents the smoke from rising to reach an upper-level detector until the fire is intense enough to overcome the cold air flow. The result can be a lower floor heavily charged with smoke and gases, and the exit path blocked before the detector alarms. Similar situations can occur with hot water heat in the winter. Users can avoid this danger by placing a detector on each level so that smoke will not have to change floors to reach the detector.



SPECIAL LOCATION CONSIDERATIONS

Many occupants of dwellings with forced air systems make the mistake of placing detectors too close to the supply register. As a result, the air stream continuously purges the smoke detector when the heating system is on.

Cold air returns can draw smoke away from the area before it reaches the detector. For this reason, avoid placing detectors between the cold air return and the bedrooms.

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In dry areas of the country, air cooling by evaporation presents an additional placement consideration. Air cooled by this method has a high relative humidity. Smoke particles are clustered and trapped in the heavy, moist air. Light, dry air rises to the ceiling, creating a barrier that may prevent cool moist smoke from reaching ceiling-mounted detectors.

Radiant panel heating in the ceiling also creates a layer of hot air that may prevent smoke from reaching the detector. Thus, detectors should be wall-mounted in homes with radiant panel ceiling heat.

BASIC PROCEDURES

There is still much to be learned in the field of smoke detector placement. However, at this point in the development of this relatively new technology, smoke detector users should review the information above, read carefully the manufacturer's instructions that accompany each unit, and follow these basic procedures:

Since smoke rises, users should install smoke detectors on ceilings or on walls between 6 and 12 inches from the ceiling.

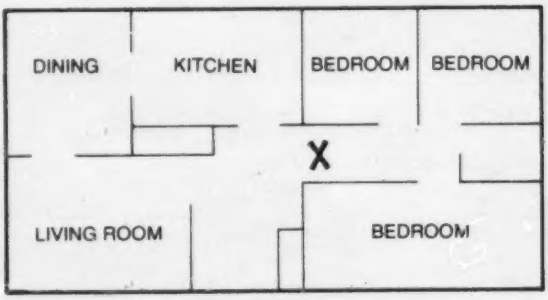
Avoid placing detectors in the "dead air" high in corners.

Do not place smoke detectors within three feet of an air supply register or between furnace air returns and the bedroom. In those circumstances where this instruction may be difficult to follow, place the smoke detector on the wall opposite the wall as close to the living area as possible.

Temperature of the mounting surface is critical. For example, the ceiling of an uninsulated attic or of a mobile home can be considerably colder than the room in the winter and much warmer during the summer. This temperature difference can create a barrier preventing smoke from reaching the detector. Therefore, smoke detectors in mobile homes should be placed on an inside wall, never on an outside wall or ceiling. Older and poorly insulated conventional homes may require detectors on inside walls or ceilings below heated spaces.

In mobile homes with a standard floor plan, the recommended general location for a smoke detector is on the wall at the end of the corridor entering the common-use areas of the home, such as the living room, dining room or family area.

In conventional homes with long central halls, users can increase potential escape time by installing a detector at each end of the hall, or installing a unit approximately every 30 feet.



The first smoke detector (indicated by cross) should be located between the sleeping area and the rest of the house.

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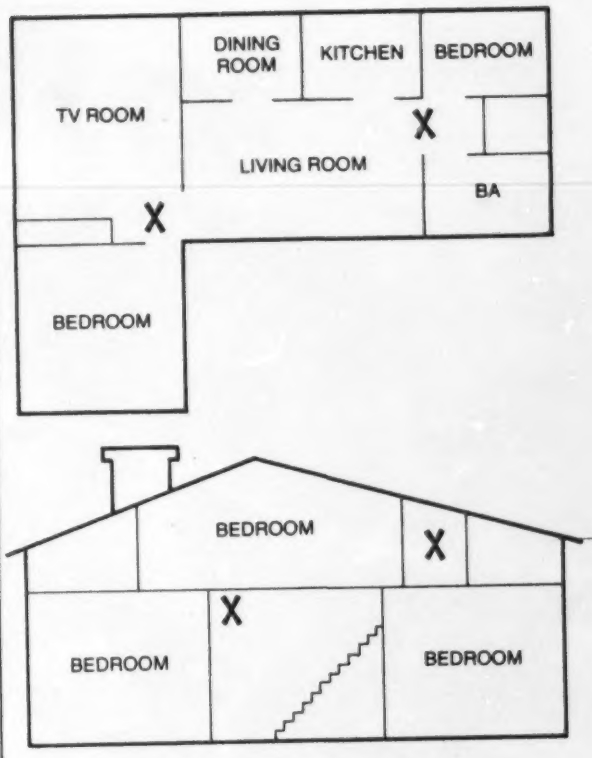
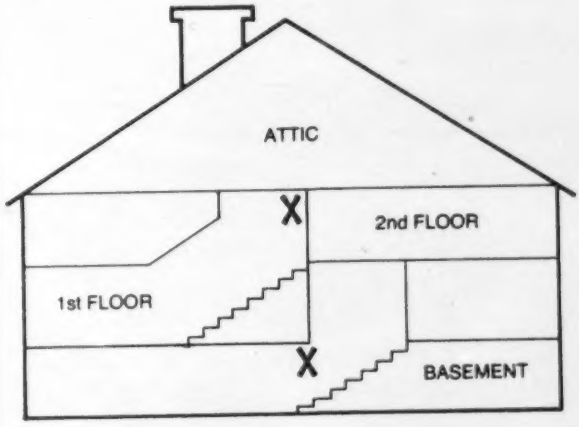
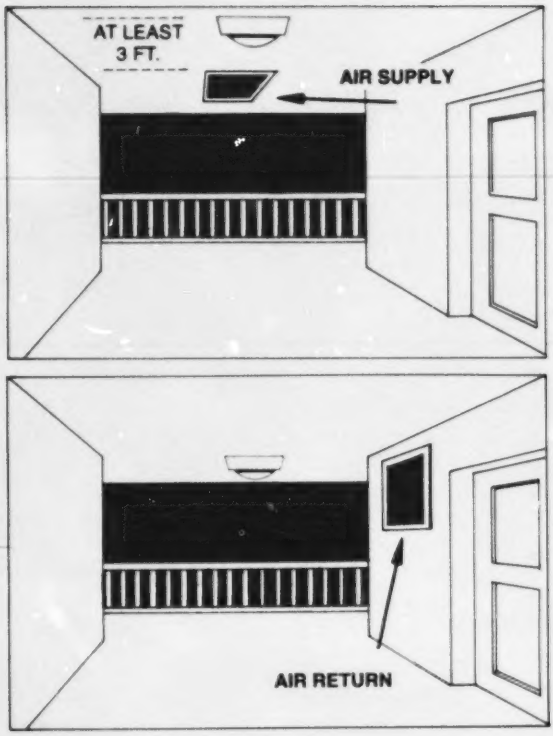


In homes with more than one sleeping area, a smoke detector (indicated by cross) should be provided to protect each.



In homes with stairs, a smoke detector should be above the bottom step of the basement stairs and at the head (top) of all other stairs.



POWER SOURCES

Batteries or household current can power residential smoke detectors. Battery operated detectors offer the advantage of easy installation: a screwdriver and a few minutes are all that is needed. Battery models are also independent of power cricuits and will operate during power failures.

Power failures are relatively infrequent in most urban areas. There is a much higher probability of people becoming complacent and not replacing batteries immediately, than of a power outage during the fire either due to utility failure or the fire itself.

Field data indicate that many purchasers of battery-operated detectors have not replaced worn-out batteries immediately. Consequently, most codes requiring detectors in newly constructed homes specify AC-powered units, since people who did not voluntarily purchase detectors are expected to be casual about battery replacement.

SPECIAL VS. ORDINARY

Additionally, some detectors require special batteries which may be difficult to find and available only by mail order in all but large metropolitan areas. While many detectors on the market take special batteries, more and more detectors require ordinary batteries. If they prefer battery-powered detectors, residents of relatively isolated areas should purchase detectors using ordinary batteries.

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In any case, it is critical that only the specific battery recommended by the detector manufacturer be used for replacement. In many instances, a unit with the wrong battery will not respond to smoke even though its test button will function.

USUALLY THE MOST RELIABLE

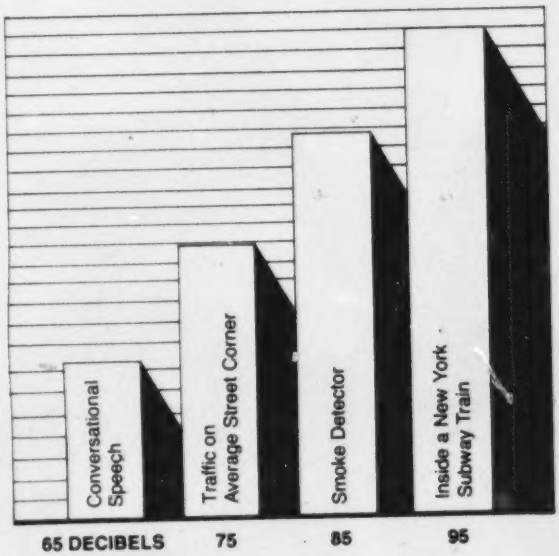
Therefore, a permanently wired, household current-powered detector is usually the most reliable mechanism. However, in some rural areas and areas with high thunderstorm occurrence, power failures may be more frequent and battery-operated units may be more appropriate.

Several manufacturers produce electrically powered units with stand-by batteries for use during power failures. However, the current stand-by battery systems do not last any longer than the primary batteries in battery-operated detectors. While possibly providing peace of mind, these units can be be inoperable during power failures if the owners have not replaced a worn-out, stand-by battery. There are currently no units on the market which have rechargeable stand-by batteries.

INTERCONNECTION AND AUDIBILITY

Audibility is critical. If the alarm cannot be heard, a smoke detector does not protect the building occupants. Loudness necessary to wake a sleeping person varies considerably with the level of background noise and is also influenced by the stage of sleep when the alarm sounds, as well as by age and physical condition. It is questionable whether a detector other than one near the bedrooms will wake sleeping occupants.

HOW LOUD ARE SMOKE DETECTORS?



To help solve this problem, many electrically powered detectors can be interconnected or "remoted" so that when one alarms, they all alarm.

Wiring between detectors is the most common method of interconnection. One or two low voltage wires are run from one detector to the other by pulling the wires through walls. This feature is provided mainly on house current-powered detectors because manufacturers feel that if a purchaser will make the effort to pull wires through walls, he will also pull in power leads to operate the detectors. People buy battery-operated detectors, the reasoning goes, to avoid pulling wires through walls.

LINE CARRIER TRANSMISSION

"Line carrier transmission" is another interconnection method. Some detectors contain a high frequency transmitter module which sends a signal back through the power lines. Receiver units containing receiving modules and horns can then be plugged into any electrical outlet. These units will sound their horns when the receiver detects the high frequency signal on the power lines. Again, since the signal has to be transmitted to the power lines, this interconnection method is only available on house current-powered detectors. Line carrier transmission operates on the same principle as wireless intercoms.

The line carrier transmitter technique has several advantages over the hard wire/interconnected. For example, the remote horns can be unplugged and plugged into any rooms in which people are present. Also, they will work in any room or building which is on the same power secondary from the utility. Thus, neighbors can exchange receivers to sound a horn in each other's home when a detector goes off. This feature is especially advantageous if the building occupants are deaf or otherwise handicapped. Line carrier units can also be used to connect remote horns from detectors installed in out-buildings on farms.

RADIO FREQUENCY TRANSMISSION

Radio frequency transmission is the third and least available method of interconnection. This system is the only one currently available for interconnect from battery operated detectors. A small transmitter (similar to an automatic garage door transmitter) is mounted adjacent to a detector and connected to it. When the detector alarms, the transmitter is activated, causing a horn to sound in a receiver unit.

This system is most often used with a radio frequency residential burglar alarm system and usually has a very limited range. While it will generally work in even the largest houses, it may not be strong enough to transmit signals to adjacent buildings or neighboring homes.

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MAINTENANCE AND TESTING

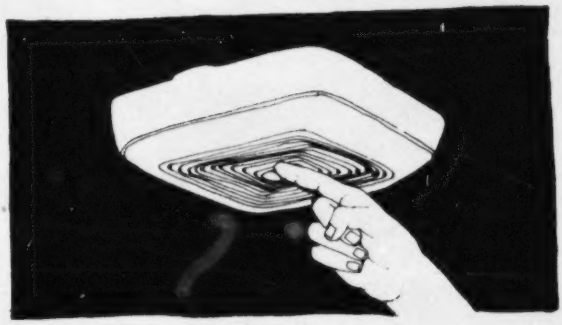
Regular maintenance and testing of smoke detectors are essential for life safety devices expected to operate perfectly even though called on only occasionally.

REGULAR CLEANING

Owners should conduct maintenance procedures outlined in the owner's manual enclosed with each detector. Cleaning is especially important. Dirt can "confuse" the detector and lead to a false alarm or cause the detector to malfunction. Vacuuming and dusting the detector, along with periodic tests, will lessen the chances of false alarm or malfunction.

EVERY THIRTY DAYS

It is very important that owners test their detectors at least once a month so that the units will not be inoperable for more than thirty days without the owner's knowledge. Testing is also recommended when the home has been unoccupied for a few days.



A SIMPLE PROCESS

Testing detectors is simple. One easy method is to drift smoke into the chamber. Some models have a test button that activates the detector. Others are equipped with a pilot light that glows or flashes while electrical power to the detector is on. Even detectors with this feature should be tested occasionally.

THE "CHIRP" ALARM

Approved battery-operated smoke detectors will sound a "chirping" alarm for about seven days when the battery needs replacing. Some types offer a 30-day low battery warning. Batteries will generally need yearly replacement.

When incandescent bulbs fail, the detector emits an intermittent signal continuously until the bulb is replaced. Some bulbs may last as long as three years, depending on operating conditions. Yearly replacement of batteries and bulbs will provide peace of mind and avoid the "chirp" alarm.

Those battery-powered detectors using light-emitting diodes (LED's) do not have a replacement alarm because of the long life of LED light sources.

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ESCAPE PLANNING

Family practice of home escape can determine survival in a fire emergency.

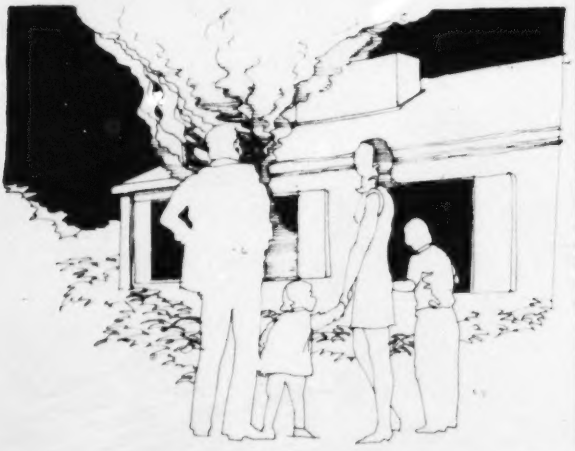
Residential smoke detectors are important but are only the first step in the escape plan crucial to fire safety. The stress situation presented by fire can cause panic and irrational behavior influenced by exposure to low levels of carbon monoxide. A carefully practiced escape plan can reduce panic, counter smoke toxicity, and help a family find its way to safety. Each step in planning home escape must involve everyone in the family.

KEY FACTORS FOR ESCAPE

Some key factors in establishing an escape plan include:

- Knowing the alarm sound and what to do when the alarm sounds in the middle of the night.

- Planning a secondary emergency exit route should the fire be building so fast that the normal exit is cut off. In multi-story homes, this may mean buying an emergency escape ladder to allow escape through a bedroom window.
- Writing down and practicing the escape plan with fire drills in the home. People should act instinctively when the detector sounds an alarm. Everyone can attain this reaction by practicing fire escape plan with all members of the family.
- Practicing crawling to safety to stay under the smoke. Remember before opening doors to touch the door knobs and top of the door to test for heat. Use the alternate escape route rather than opening a hot door.
- Immediately leaving and going to a pre-arranged meeting place outside the house when the detector alarms. A tree, street light, or a neighbor's home can be the meeting place. This is very important since numerous people have been killed when they have gone back into a burning house looking for someone who has already escaped.
- Never stopping to call a fire department from the home. Fires can build at amazing speed and the occupant may be cut off or even killed while on the phone. Call the fire department from a neighbors' home.
- Never re-entering the home once you have left.



Again, a smoke detector itself cannot save the family unless that family takes the proper actions when the detector alarms. A planned reaction to the smoke detector alarm may determine survival.

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FOR ADDITIONAL READING

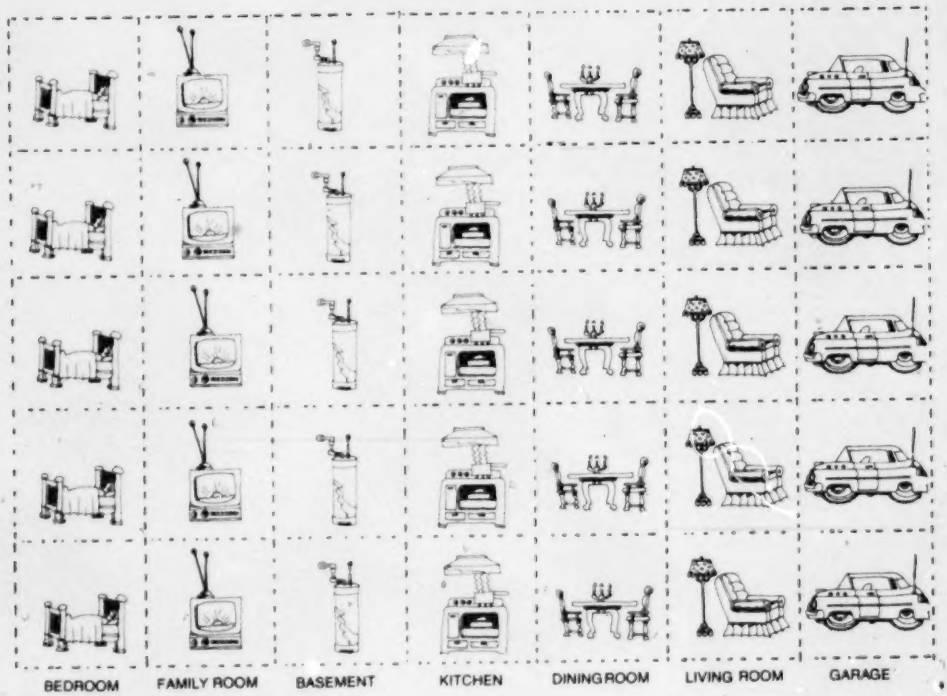
1. **Field Investigation of Residential Smoke Detectors,** R. W. Bukowski, NBSIR 76–1126, NTIS #PB–260878. Hard copy $4.50, microfilm, $3.00. National Technical Information Service, Springfield, Virginia 22161.

2. **Detector Sensitivity and Siting Requirements for Dwellings,** R. W. Bukowski, et al, NBSGCR 76–51, NTIS #PB–247483. Hard copy, $10.00, microfilm, $3.00. National Technical Information Service, Springfield, Virginia 22161.

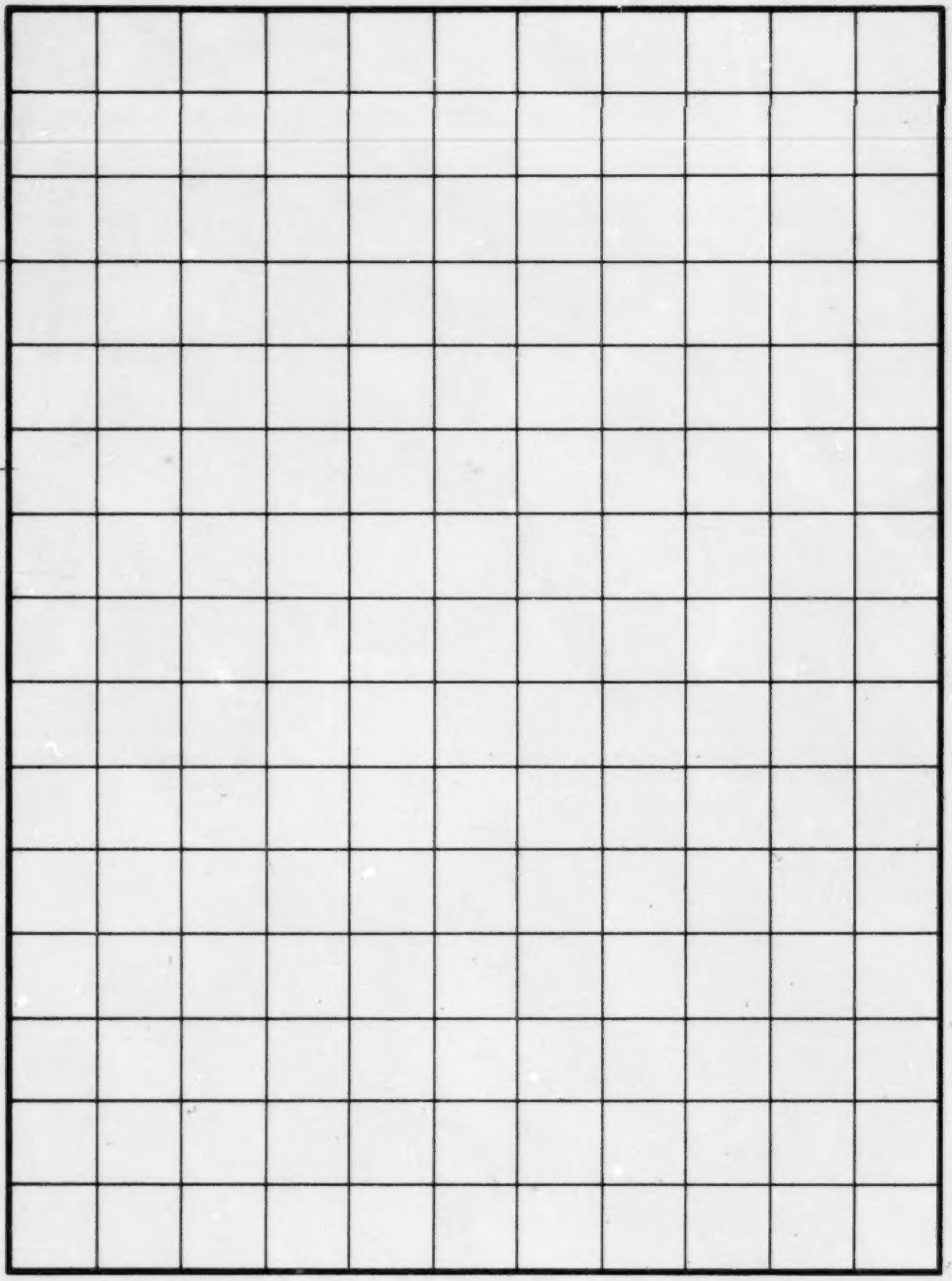
3. **Recent Advances in Residential Smoke Detection,** R. G. Bright, NFPA Fire Journal, Vol. 68, No. 6, November 1974.

4. **Life Saving Investments—Smoke Detectors for the Home,** F. P. McGehan, NBS Dimensions, Vol. 60, No. 4, April 1976, National Bureau of Standards, Washington, D. C. 20234 SD Catalog #13.13:60/4, $.80. Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402.

5. **Fire Detection, The State-of-the-Art,** R. Custer, R. G. Bright, NBS Technical Note 839, SD Catalog #C13.46:839, $1.55. Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402.



FLOOR PLAN OF YOUR HOME



Draw the floor plan of your own home on the grid above, indicating exits and emergency escape routes. Use symbols from opposite page to identify each room. Post the floor plan where all members of your household can study it, and familiarize each member with the proper routine for safe exit in case of a fire emergency.

NOTES

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